

The Leakage of Helium from Radio-Active Minerals

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experimental values of the mobilities in the different gases at various pressures, as well as certain observed deviations from the law connecting the mobility and gaseous pressure, can be explained approximately on the supposition that the ion consists of a single molecule of the gas with which is associated a charge equal to that carried by the monovalent ion in electrolysis.

The Leakage of Helium from Radio-active Minerals.

By the Hon. R. J. STRUTT, F.R.S., Professor of Physics, Imperial College of Science, South Kensington.

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In a paper published in 'Roy. Soc. Proc.' A, vol. 81 (1908), p. 272, I showed that phosphatised bones and similar materials were notably radio-active, and that helium could be detected in them. The quantity of helium found was not, however, uniformly greater in the geologically older materials than in younger ones of equal activity. This was hypothetically attributed to escape of helium in certain cases. I desired if possible to obtain direct experimental confirmation of this conjecture.

It would clearly be impossible to detect leakage of helium from materials such as the mineralised bones, even in a lifetime. For any chance of success it was necessary to have recourse to the ores of uranium and thorium, in which the quantity of helium is something like 100,000 times greater.

The method of experimenting was to place a considerable quantity of the ore (usually a kilo or more) in a bottle provided with an exit tube and stop-cock and connected to a mercury pump. The bottle was exhausted and the stopcock closed. After the lapse of a definite interval of time, usually a day or more, a small quantity of oxygen was admitted to the bottle and then collected through the pump, carrying with it any helium which had come off from the mineral. The oxygen was absorbed with melted phosphorus, leaving a small residue of helium, together with impurities. Any hydrogen present in the original gas, which may have been liberated by radio-active decomposition of traces of moisture, was burnt along with the phosphorus, and thus got rid of. The residue was transferred to an apparatus consisting of a McLeod gauge in connection with a reservoir containing charcoal. On cooling the charcoal with liquid air, helium was isolated, and the quantity could be measured. As a test of purity, the spectrum could be examined in the capillary measuring tube of the gauge, using external tinfoil electrodes.

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I was astonished at the quantity of helium observed in the first experiments. It exceeded anticipation by hundreds, or even thousands, of times. I shall not describe the experiments in the order in which they were made, but rather in that which seems to connect them best.

It was found that after a radio-active mineral had been powdered, helium was evolved from it, rapidly at first, then at a diminishing rate. The following observations illustrate this.

A quantity (337 grammes) of monazite from the Transvaal was powdered and passed through a wire-gauze sieve of 120 threads to the inch. This took about one hour. Immediately afterwards it was put in a bottle and the air pumped out. The rate of evolution of helium in cubic millimetres per day per kilo of material was as follows:—

Time (days).	Rate.
0·031	261
0·59	76·6
1·6	17·1
2·6	12·3
4·6	9·57
10·6	4·38
33·0	1·14

The first experiment was made as quickly as possible, helium being collected for one hour. Times are measured from the moment when the powdering was half completed to half-way through the period of accumulation. Naturally the first rapid variations can only be roughly investigated in this way.

Leakage of helium from this sample is still continuing, and it is intended to watch its future course.

It will be observed that the whole quantity which has escaped while the mineral has been under observation is but an insignificant fraction (probably less than a 500th*) of the whole quantity present.

Moss† has observed that quantities up to 1 per cent. of the helium contained in a mineral can be liberated by grinding in a vacuum. The present observations show that this is but the first rapid stage of a long-continued leakage of helium from the newly created surfaces. The view that heat generated in grinding is the important factor appears untenable; for in that case escape of helium should cease on cooling.

It is uncertain how long this evolution of helium continues; in all

* This sample of monazite was very poor in helium, containing only $\frac{1}{10}$ c.c. per gramme.

† 'Roy. Dub. Soc. Trans.,' vol. 8, p. 153.

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probability, however, the period is prolonged: and since the majority of radio-active materials can only be obtained in the form of pieces which have been broken off from their natural home a moderate number of years back, any observations made upon them are inconclusive as to the rate at which helium escapes when they are undisturbed in their original surroundings.

It was found, in fact, that pieces from the same stock of monazite, about the size of a lump of sugar, which had not been fractured since they came into my possession two years ago, evolved helium at the rate of 0.002 c.mm. per kilo of material per diem.

This rate, though quite insignificant in comparison with that exhibited by the powdered material, is much in excess of the probable rate of generation of helium by radio-active change. It follows that the present stores of helium could never have been accumulated had the present rate of evolution prevailed throughout the life-history of the mineral.

With a view to testing a mineral more nearly in its natural condition, experiments were made on thorianite, which occurs in gravels, in detached cubic crystals, washed out of their original matrix. This, too, showed a considerable leakage of helium (0.069 c.mm. per kilo per diem). Tests were made at intervals over a considerable period. The rate was found quite uniform, the volume of helium pumped out being proportional to the time of accumulation. A second collection, made immediately after the first, yielded scarcely anything. It is difficult to account for this large evolution of helium from a mineral so nearly in its natural condition. It was thought possible that an explanation might be found by supposing that the temperature of the laboratory (65° F.) was somewhat higher than that of the natural surroundings of the mineral. The latter must, however, be above the freezing point; and it was decided to test experimentally the rate of evolution at that temperature. The bottle containing the mineral was kept in ice for some days; under these conditions the helium leakage was reduced to about a quarter of its value at the higher temperature (0.018 c.mm. per kilo per day). This is still greatly in excess of the rate of accumulation.

It seemed possible, though unlikely, that the mineral, when kept in a vacuum, lost helium which it would have retained at atmospheric pressure. To test this explanation, the bottle containing the mineral was left filled with oxygen up to atmospheric pressure. At the close of several days the oxygen was pumped out, and absorbed with phosphorus. The ordinary quantity of helium was obtained, the rate of escape being undiminished.

It was noticed that the surfaces of some of these crystals were somewhat weathered. With the idea that this might determine the escape of helium, another sample of thorianite much fresher in appearance was tested. The

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rate of evolution in this case was only 0.0127, about one-fifth of that observed with the previous sample.

The majority of minerals allow water to percolate through them. The effective superficial area must therefore much exceed the external surface.

It is probable that loss of helium occurs from the weathering of these interior surfaces as well as from the external faces of the crystals. Abrasion of the external surfaces by comparatively recent rolling in water-courses may have produced some effect.

Under laboratory conditions the rate of escape of helium from minerals always far exceeds the rate of production by radio-active change. Therefore the conditions under which the life of the minerals has been mainly passed, deep down in the earth, where atmospheric agencies have no place, must be supposed more favourable to retention of helium, for otherwise the present accumulation could never have been formed. The observations here recorded leave little room for surprise that fossilised bones and other materials do not always contain as much helium as would be expected from their radio-activity and geological age.

On the Electricity of Rain and its Origin in Thunderstorms.

By GEORGE C. SIMPSON, D.Sc.

(Communicated by Dr. Gilbert T. Walker, F.R.S. Received January 6,—Read February 4, 1909.)

(Abstract.)

During 1907–08 an investigation was undertaken at the Meteorological Office of the Government of India, Simla, into the electrical phenomena which accompany rain and thunderstorms.

Two lines of research were adopted :—

(a) A systematic record was obtained by means of self-registering instruments of the electricity brought down by the rain throughout one rainy season.

(b) Laboratory experiments were made with the object of determining the source of the electricity of thunderstorms.

The chief results of the first part of the work may be briefly summarised as follows :—